PATENT SPECIFICATION (11) 1 405 048

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(21) Application No. 46712/73 (22) Filed 5 Oct. 1973 (19)
(31) Convention Application Nos. 100 996/72 (32) Filed 6 Oct. 1972
46929/73 24 April 1973 in
(33) Japan (JA)
(44) Complete Specification published 3 Sept. 1975
(51) INT. CL.[2] G06F 3/00
(52) Index at acceptance
G4A 10EX 3W10Y 5A 9F
B6F 6B8B1 6B8BY 6B8G1 6B8GY

(54) CALCULATOR CONSTRUCTION AND METHOD FOR MAKING CALCULATOR

(71) We, SHARP KABUSHIKI KAISHA, a Japanese company, of 22—22 Nagaike-cho, Abeno-ku, Osaka, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates generally to an electronic calculator, and more particularly to a calculator construction and a method of making an electronic calculator.

In accordance with known electronic calculator constructions, the function units thereof, namely, a display unit employing fluorescent indicator tubes, light-emitting diodes, etc., a semiconductor circuit unit including various arithmetic and logic circuit elements, and a key input unit for manually introducing functional commands into the semiconductor circuit unit, are clearly distinct components and the individual components or units are connected together by a number of lead wires. Then, the components or units coupled in such manner are housed in a single case, thereby completing fabrication of the calculator. Although calculators constructed in this way are supplied as a single unit, the internal components in practice are physically independent of each other except for their electrical interconnections. Furthermore, an undesirably large amount of space is required to accommodate the connections between the individual components, the actual amount of space needed depending on wiring and soldering technology. For these reasons, difficulties have been encountered in arriving at an electronic calculator construction having not only the required reliability as regards its electrical interconnections but also a sufficiently small size to be practical for use in a battery powered calculator. In addition, the manufacturing processes for known calculators are complex and not suited for mass production.

According to one aspect of the present invention, there is provided a calculator comprising a keyboard unit, a computation circuit and a display unit, the keyboard and display units each including a plurality of sets of electrodes, said computation circuit and at least one of the electrodes of each of said sets being directly formed on a common substrate.

According to another aspect of the invention, there is provided a method of making an electronic calculator comprising forming directly on a dielectric substrate; a circuit including a computation circuit, a keyboard unit and a display unit.

An electronic calculator, and a method of making the electronic calculator, in accordance with the invention, will now be described, by way of example, with reference to the accompanying drawings, in which:—

Figure 1 is a sectional side view of an electronic calculator embodying the principles of the present invention;

Figures 2 and 3 are exploded perspective views of parts of the electronic calculator of Figure 1;

Figure 4 is a plan view of the electronic calculator at a particular stage in the manufacturing process;

Figure 5 is a sectional view of a keyboard unit employed in the electronic calculator; and

Figure 6 is a flow chart showing a sequence of fabrication processes for making the electronic calculator in accordance with the teachings of this invention.

Referring now to Fig. 1 illustrating one form of an electronic calculator embodying this invention, a substrate 1 is constituted by an extended portion of an electrode supporting plate within a liquid crystal display unit 2 and is made of dielectric material, such as glass, ceramic, or plastics material. A semiconductor circuit unit 3 containing various circuit elements and interconnections therebetween is directly mounted on a major surface or rear surface A of the substrate 1 while a keyboard unit 4 is directly mounted

on the other major surface or front surface B. The liquid crystal display unit 2, the semiconductor circuit unit 3 and the keyboard unit 4 which are unified as a single component on the same plate 1, are accommodated in a package or casing 5 of, for example, plastics material. The package 5 is comprised of an upper cabinet 6, a lower cabinet 7 and a hood 8 for covering or uncovering an indication surface of the display unit 2 when necessary. A plurality of openings are formed in the upper cabinet 6 to install key tops therein.

The hood 8 may rotates about the coupling of the upper and lower cabinets 6, 7 within a predetermined angular range (e.g. 45°) and, in the illustrated embodiment, is provided with a window or transparent portion 9 which allows ambient light to illuminate the indication surface of the display unit 2 when the hood 8 is in the open state. The transparent portion 9 preferably consists of plastics material in the form of a lens. Surrounded by the upper and lower cabinets 6, 7, at one end of the calculator, is a cavity 10 to accommodate a power cell 11 therein. In order to reduce power dissipation, provision is made for automatically enabling the power supply to the circuit unit 3 and the display unit 2 when the hood 8 is in the open state and automatically inhibiting the power supply when the desired arithmetic operations are completed and the hood 8 is closed. This provision is accomplished by the installation of a switch (not shown), associated with opening and closing movements of the hood 8, for the power cell 11.

Details of the liquid crystal display unit 2, the semiconductor circuit unit 3 and the keyboard unit 4 generally illustrated in Fig. 1 will be clearer from the following detailed description with reference to Figures 2 to 5 inclusive.

Figure 2 is an exploded perspective view illustrating the liquid crystal display unit 2 and the semiconductor circuit unit 3 which are both directly formed on the rear surface A of the substrate 1. As previously described, the multi-digit display unit 2 comprises a plurality of liquid crystal display elements of known construction each of which has, for example, a layer of nematic liquid crystal composition of a type that scatters light due to turbulence in the layer creater by the application of a voltage across the layer. On the transparent substrate 1, which may be of glass, are formed individual segment electrodes 12 each consisting of a transparent conductive film such as SnO_2, In_2O_3, together with electrode leads 13. In this manner, the substrate 1 also constitutes the transparent electrode (supporting) plate for the liquid crystal display unit.

Interconnections 14 between the liquid crystal display unit 2 and the circuit unit 3 are made in the desired interconnection pattern over the whole surface of the substrate 1 by the use of printed circuit technology known in the art. It is preferable that multilayer interconnections (two layers) 15 are employed with intervening layers of dielectric material to increase the density of interconnection. These multilayer interconnections can be seen from the outside by using intervening dielectric material layers of, for example, semitransparent low melting-point glass. Connection holes 16 serve in the connection between the upper and lower films within the multi-layer interconnection. It is, in fact, difficult to align all the electrode leads 13 for the individual segment electrodes 12 within the display unit area, in view of the configuration and the number of the segment electrodes 12. To this end, a space 17 is disposed above the display unit area, in which the electrode leads 13 are formed and tied to the semiconductor circuit unit 3 as they extend from one side to the other of the display area 18. The interconnections extending from one side to the other are formed of transparent conductive film.

After formation on the substrate 1 of the individual segment electrodes 12 and the interconnection 14 (interconnections within the circuit unit 3 will be described later), a glass plate 21 is attached and adhered through a spacer 20 in a position corresponding to the display unit area. The substrate 1 having the segment electrodes 12 formed thereon serves as the first electrode supporting plate while the glass plate 21 serves as the second electrode supporting plate. Conventional Al vapor deposition and other methods can be used in applying a common reflective electrode 22 for each digit display element on the glass plate 21. The first and second electrode plates 1, 21 and the spacer member 20 together form a cavity for the nematic liquid crystal composition. The liquid crystal display unit 2 of the reflection kind is provided in this way. The spacer member 20 may be either dielectric material such as mica, polyethylene telephthal film, or a bonding agent such as glass frit. The common electrodes 2 deposited on the second plate 21 extend to the predetermined interconnections 15 on the substrate 1 through electrode leads 23 on the glass plate 21 and silver paste on connection pins 24. In the illustrated embodiment of this invention, the electrode leads for the liquid crystal display unit 2 are all introduced on the same substrate 1 and are appropriately connected to other various components or units. The liquid crystal display unit provides, for example, eight-digit digital indication as well as indicating sign symbols +, − or constant calculation symbols K at the most right (or left) position. With such

an arrangement, the display unit 2 will provide a visual indication of operation results in response to enabling signals from the semiconductor circuit unit 3.

On the other hand, the semiconductor circuit unit 3 comprises of several LSI (large-scale integrated circuit) elements 25, 25^1 and interconnections 26 formed in the desired pattern on the substrate. 1 using known printed circuit technology. Provision for the interconnections 26 can be accomplished by printing and sintering gold paste on the substrate 1. Also, multi-layer interconnections may be employed if necessary. The LSI elements 25, 25^1 are installed on the substrate 1 by soldering technology in such a manner that the individual leads thereof are connected to previously plated solder layers 27 which in turn are connected to the interconnections. More specifically, in contrast with the conventional LSI packages, the LSI element 25 illustrated in Fig. 2 has signal leads 28, which have been previously coated with solder, on its vertical sides. The LSI element 25 is first placed on the substrate 1 in such a way that the individual leads 28 are in physical contact with the solder layers 27. The junctions between leads 28 and solder layers 27 are coated with soldering paste and heated with a soldering iron so that the solder is well melted at the junctions to provide electrical good connections. This sequence of operations needs less solder and allows for easy soldering connections.

The interconnections associated with the liquid crystal display unit 2 and the semiconductor circuit unit 3 are formed at the same time by using a printed circuit method employing gold paste or other materials. It is, therefore, not necessary to form these interconnections in separate processes. If the printing procedure is performed after deposition of low melting-point glass frits on the substrate 1, then very tight bonding will result between the printed interconnection layers and the substrate. In addition, the interconnection layers can be sealed with low melting-point glass for ensuring improvements in electrical isolation and resistance to wear. Check terminals 29 are provided for sensing signals which occur in the semiconductor circuit unit 3.

Figure 3 is an exploded perspective view illustrating the construction and arrangement of the keyboard unit directly formed on the front surface B of the substrate 1. The keyboard unit illustrated there is comprised of comb-shaped electrodes 31 for key switches or contacts formed in accordance with the teachings of printed circuit technology using gold paste, silver paste or other suitable materials, a plurality of signal terminals 32 for key coupling to the circuit unit 3, several power accepting terminals 33 and ground terminals 34 for a common spring plate to be described later. Guide lines may be written in the course of the printing treatment for the deposition of contact electrodes 31 to assist installation of rubber switch contacts to be described later on the substrate 1. Needless to say, the contact electrodes 31, the signal terminals 32 and the power accepting terminals, are connected together by printed circuit lines (not shown) which are directly formed on the substrate together with the ground potential terminal 34 and the guide lines 35 at the same time by printing and sintering procedures. One way of forming connections between individual units directly constituted on the two surfaces A, B of the substrate 1 is to employ a multi-pin connector 36 comprising a dielectric film 36 and a set of "U" shaped shunting pins 38 each being in contact with the individual signal terminals 32. Provision of such connectors 36 enables arithmetic instruction signals originated in response to key depression to be transferred to the semiconductor circuit unit 3 directly formed on the rear surface A of the substrate 1 via the individual shunting side pins 38. It will be noted that other conventional methods, such as conductive material printing through holes, or wire bonding may be used. A power supply circuit (in this example, DC—DC converter) unit board 39 is positioned adjacent one side of the substrate 1 in view of the requirement for miniaturization of home-use calculators. This board 39, which carries various power circuit parts or elements associated with the cell 11, is secured to the substrate 1 through a coupling arrangement including a dielectric film 40, and conductive pins 41 inserted in holes 43 in the board 39, such that the specified points in the power supply circuit are electrically coupled to the power accepting terminal 33 on the front surface B and the predetermined points on the rear surface A. Soldering is carried out about the holes 43 for coupling between the pins 41 and the power board 39. In the illustrated embodiment, one end portion of the power board 39 extends beyond the substrate 1 and thus the cavity 10 in which the power cell 11 and holder 44 are housed is formed by a space about such extended portion of the board 39. The relative positions of the cell 11 and the power board 39 with respect to the substrate 1 will be best understood from Fig. 4, wherein the key electrode areas are all covered with a single rubber plate 45.

The rubber plate 45, which comprises a dielectric rubber base 46 having a predetermined number of dome-shaped projections 46^1 and conductive rubbers 47 (Fig. 5) tightly affixed to the inner wall of the projections 46^1, cooperates with the comb-shaped electrodes directly formed on the front surface B to constitute a predetermined number of

WHAT WE CLAIM IS:—

1. A calculator comprising a keyboard unit, a computation circuit and a display unit, the keyboard and display units each including a plurality of sets of electrodes, said computation circuit and at least one of the electrodes of each of said sets being directly formed on a common substrate.

2. A calculator as claimed in claim 1, wherein the substrate is of a dielectric material.

3. A calculator as claimed in claim 1 or claim 2, wherein said computation circuit comprises a semiconductor circuit.

4. A calculator as claimed in any one of claims 1 to 3, wherein the display unit comprises at least one display cell of the liquid crystal type.

5. A calculator as claimed in claim 4, wherein the liquid crystal display cell comprises a pair of electrodes, a liquid crystal composition between the electrodes and a pair of electrode supporting plates one of which is said substrate.

6. A calculator as claimed in claim 5, wherein the cell is part of a multi-digit liquid crystal display unit, one of said pair of plates being arranged to support all the ones of electrode pairs for the individual digit cells and the other of said pair of plates being arranged to support all the others of the electrode pairs for the individual digit cells.

7. A calculator as claimed in claim 6, wherein the keyboard unit comprises a plurality of key switches each comprising a movable contact made of elastic material and a stationary contact of conductive material, the individual stationary contacts being directly formed on said substrate.

8. A calculator as claimed in claim 7, wherein the keyboard unit includes a spring plate comprising a plurality of spring action areas one for each of the individual key switches, the spring action area being of spiral configuration with a pair of pivoting axes.

9. A calculator as claimed in claim 8, wherein the spring plate is made of conductive material and is tied in use to ground potential.

10. A calculator as claimed in any one of claims 3 to 9, wherein the substrate has two major surfaces, the keyboard unit is formed on one of the major surfaces of the substrate, and the display unit and computation circuit are both formed on the opposite major surface of the substrate.

11. A method of making an electronic calculator comprising forming directly on a dielectric substrate; a circuit including a computation circuit, a keyboard unit and a display unit.

12. A method as claimed in claim 11, comprising the steps of preparing two distinct dielectric substrates for a liquid crystal display unit, depositing electrodes on the dielectric substrates respectively, depositing electrical interconnections on major surfaces of the one of the dielectric substrate and a predetermined number of stationary contacts for a keyboard unit simultaneously, adhering the dielectric substrates carrying the electrodes for the display unit to each other, filling with a liquid crystal composition a cavity between the dielectric substrates, installing a semiconductor circuit unit containing at least a computation circuit on the one of the dielectric substrates, installing a rubber plate having the predetermined number of movable contacts above the dielectric substrate in a manner to correspond to the individual stationary contacts respectively, and housing the dielectric substrate directly carrying the liquid crystal display unit, the semiconductor circuit unit and a portion of the keyboard unit in a casing.

13. A method as claimed in claim 12, wherein the deposition of said electrical interconnections includes the utilisation of a conductive paste.

14. A electronic calculator substantially as hereinbefore described with reference to the accompanying drawings.

15. A method of making an electronic calculator substantially as hereinbefore described with reference to the accompanying drawings.

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Printed for Her Majesty's Stationery Office by Burgess & Son (Abingdon), Ltd.—1975.
Published at The Patent Office, 25 Southampton Buildings, London, WC2A 1AY
from which copies may be obtained.

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4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 1

FIG.1.

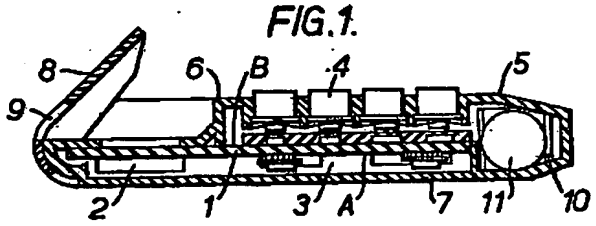

FIG.2.

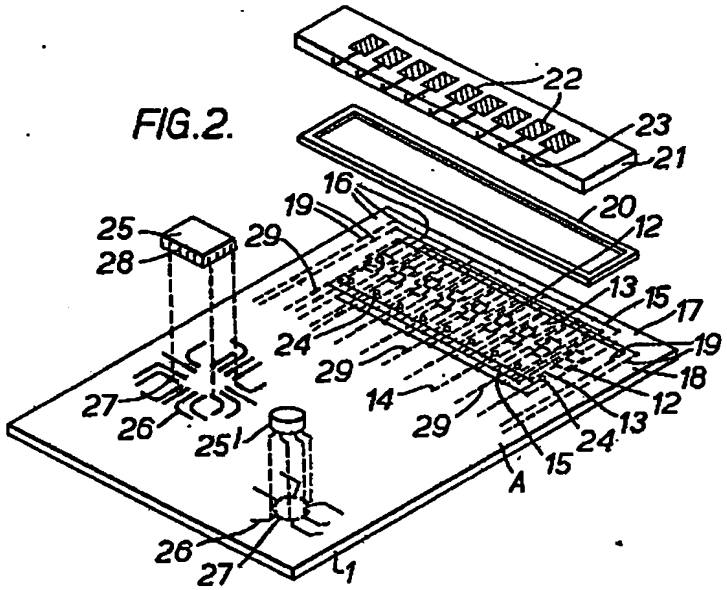

FIG.3.

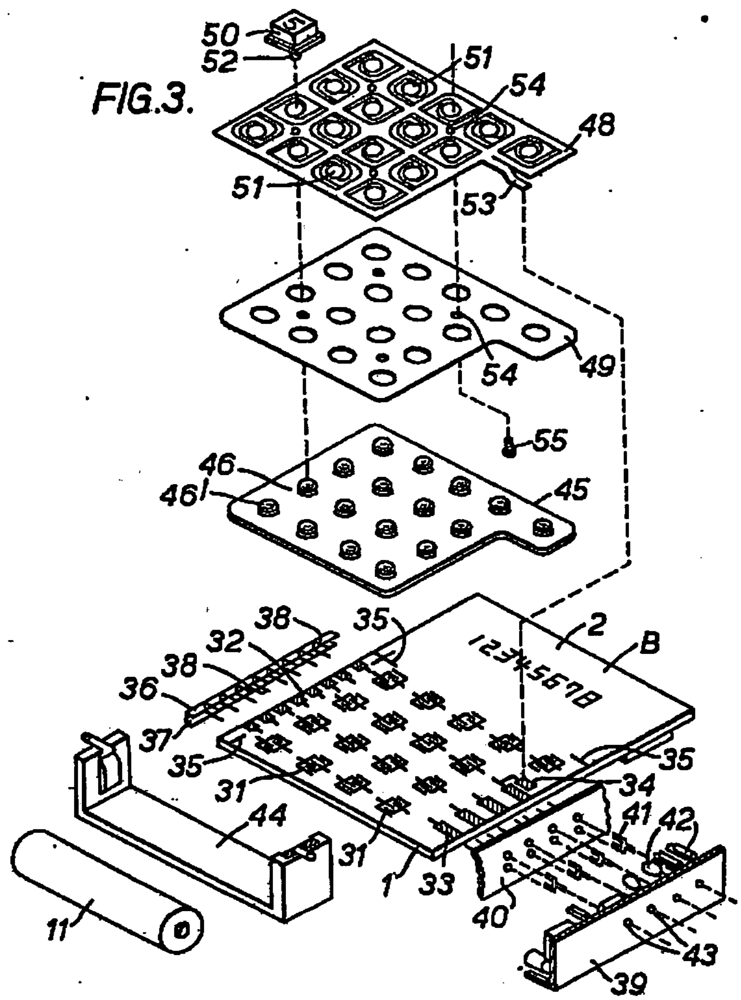
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FIG. 4.

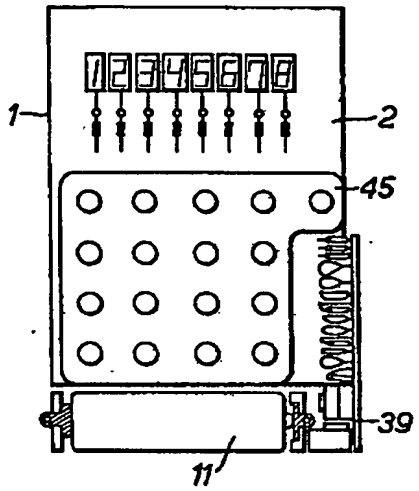


FIG. 5.

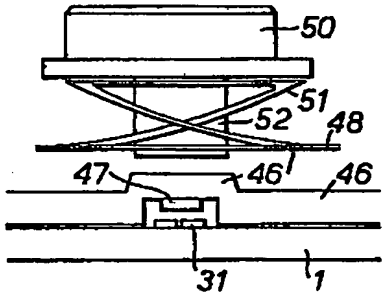
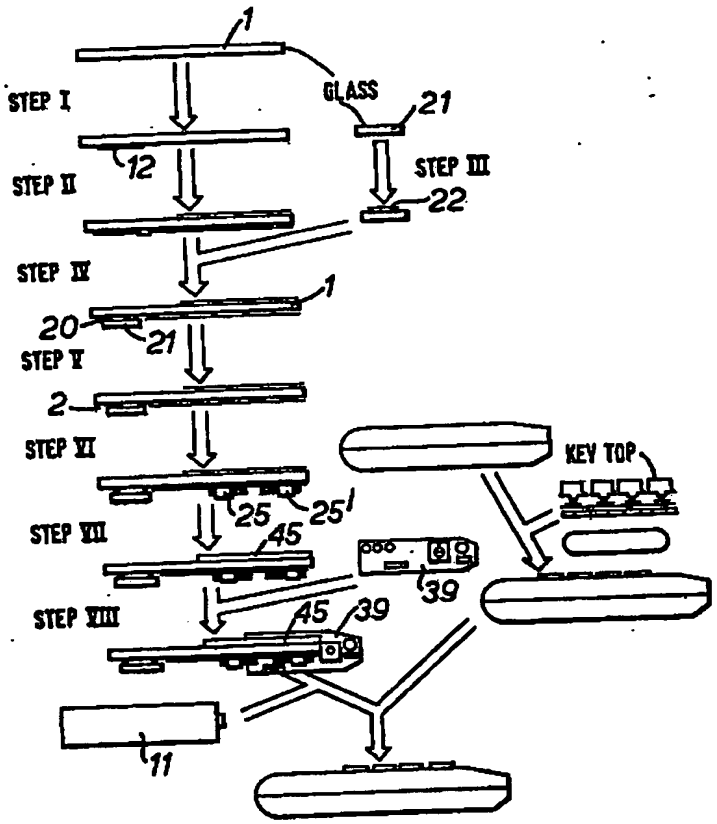


FIG.6.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